C-6.1 Summarize the process by which solutes dissolve in solvents, the dynamic equilibrium that occurs in saturated solutions, and the effects of varying pressure and temperature on solubility.

Revised Taxonomy Level 2.4 <u>Summarize</u> conceptual knowledge

In physical science, students

- Distinguish chemical properties of matter (including reactivity) from physical properties of matter (including boiling point, freezing/melting point, density [with density calculations], solubility, viscosity, and conductivity). (PS-3.1)
  - *In reference to solubility*
    - Understand the term solubility only in terms of whether or not a substance will dissolve.
    - Be able to give examples of solids, liquids, and gasses that readily dissolve in water.
    - Understand the components of solutions (and therefore mixtures) do not chemically combine to form a new substance and therefore, solutions are composed of two substances which each retain their own properties.
      Therefore solubility is a physical property.
- Explain the effects of temperature, particle size, and agitation on the rate at which a solid dissolves in a liquid. (PS-3.5)

Note to teachers: In Physical Science, solubility is defined as a physical property because solutions are defined as homogeneous mixtures. However, as students study chemistry they will find that the dissolving process varies with the characteristics of the solute and the solvent respectively. The attraction of various solute particles to water molecules varies and if this force is strong, the dissolving process is considered a chemical reaction.

- **It is essential for students to**
- Distinguish between solutions, suspensions, and colloids on the basis of
  - Particle size
  - Settling behavior
  - Capacity to be separated by filtration
  - Capacity to scatter light (Tyndall Effect)
- Describe the formation of a liquid solution
  - Breaking up of the solute into individual components (expanding the solute)
  - Overcoming intermoleculear forces in the solvent to make room for the solute (expanding the solvent)
  - Interaction between the solvent and the solute to form the solution
- Explain solution equilibrium in terms of La Chatliers' Principle

- Distinguish among the following conditions
  - Saturated solution: a solution which contains the maximum amount of solute under the existing conditions (temperature, and volume of solvent)
    - Understand solubility as the amount of substance required to form a saturated solution with a specific amount of solvent at a specified temperature.

- Unsaturated solution: a solution which contains less than the maximum amount of solute under the existing conditions (temperature, and volume of solvent)
- Supersaturated solution: a solution that contains more dissolved solute than a saturated solution contains under the same conditions.
- Understand the effect of pressure on the solubility of gasses in liquids.

❖ Distinguish among strong electrolytes, weak electrolytes, and nonelectrolytes
❖ Understand the effect of temperature on solubility of solids in liquids, gasses in liquids, and liquids in liquids

Assessment
The revised taxonomy verb, summarize means "to abstract a general theme or major point" For this indicator, the major focus of assessment should be to insure that students have a conceptual understanding of the terms and concepts associated with the process of solvation. Conceptual knowledge requires that students understand the interrelationships among the basic elements within a larger structure that enable them to function together. In this case, that students understand the interrelationships among the factors that effect the process of salvation.

C-6.2 Compare solubility of various substances in different solvents (including polar and nonpolar solvents and organic and inorganic substances).

Revised Taxonomy Level 2.6 Compare conceptual knowledge

Students did not study this concept in physical science

It is essential for students to

- Understand the observation that "like dissolves like"
  - compare polar and nonpolar solvents in terms of
    - Structure
    - Organic vs. inorganic substance
    - Common examples
- Predict conditions which favor solubility of a particular solute in a given solvent based on
  - The structure of the solvent
  - The structure of the solute
  - The temperature
  - The pressure
- Give examples of solutions composed of substances which exist in various phases at room temperature.
  - Gas dissolved in gas
  - Gas dissolved in liquid
  - Gas dissolved in solid
  - Liquid dissolved in liquid
  - Liquid dissolved in solid
  - Solid dissolved in solid

Assessment

As stated in the indicator, the major focus of assessment is to compare (detect correspondences) in the degree to which various solutes will dissolve in various solvents based on the factors which influence solubility. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students understand not only the way that each factor affects solubility but also the reasons that each factor affect solubility.

C-6.3 Illustrate the colligative properties of solutions (including freezing point depression and boiling point elevation and their practical uses).

Revised Taxonomy Level 2.2-B Exemplify (illustrate) conceptual knowledge

Students did not study this concept in physical science

It is essential for students to

- Understand that colligitave properties are properties that depend on the concentration of solute particles but not on their identity.
- Describe melting point depression and boiling point elevation qualitatively in terms of Kinetic Molecular Theory
  - Explain how the concentration of the solution may differ from the concentration of the solute particles.
- Discuss causes of the differences between expected and experimentally observed colligative properties of electrolytic solutions.
- Identify practical uses for the colligative properties of solutions.

Assessment

The verb exemplify (illustrate) means to find a specific example or illustration of a concept or principle, therefore the major focus of assessment should be for students to give examples that show that they understand how the concentration of the solute particles in a solution affect colligative properties. Conceptual knowledge requires that students understand the interrelationships among the basic elements within a larger structure that enable them to function together. In this case, that students understand how the colligative properties of substances in solutions are affected by the number of solute particles in terms of the Kinetic Molecular Theory.

C-6.4 Carry out calculations to find the concentration of solutions in terms of molarity and percent weight (mass).

Revised Taxonomy Level 3.2 C_A Apply (carry out) procedural knowledge
Students did not study this concept in physical science

It is essential for students to

- Solve problems involving the Molarity of a solution (moles of solute per volume of solution) (moles/liter)
  - Molarity (M)
  - # moles of solute
  - Volume of solution
  - Mass of solute
- Determine the percent weight (mass) of a solution (mass of solute/mass of solution x 100) (%)

Assessment

The revised taxonomy verb for this indicator is implement (apply), the major focus of assessment should be for students to show that they can "apply a procedure to an unfamiliar task". The knowledge dimension of the indicator, procedural knowledge means "knowledge of subject-specific techniques and methods" In this case the procedure for quantitatively finding the concentration of a solution in terms of Molarity or percent weight. A key part of the assessment will be for students to show that they can apply the knowledge to a new situation, not just repeat problems which are familiar. This requires that students have a conceptual understanding of Molarity and percent weight.

C-6.5 Summarize the properties of salts, acids, and bases.

Revised Taxonomy Level 2.4 <u>Summarize</u> conceptual knowledge

In physical science students

- **Classify various solutions as acids or bases according to their physical properties, chemical properties (including neutralization and reaction with metals), generalized formulas, and pH (using pH meters, pH paper, and litmus paper). (PS-3.8)**

It is essential that students

- Describe the properties of acids, including
  - The Arrhenius Definition of an acid as a molecular substance that ionizes, releasing hydrogen ions when it is mixed with water.
  - The reaction of acids with metals that are chemically active to produce hydrogen gas
  - The effect of acids on indicators
  - Neutralization of bases
  - Sour taste
  - Have a pH less than 7
- Describe the properties of bases, including
  - The Arrhenius Definition of a base as a substance whose water solution releases hydroxide ions as the only negative ions when it is mixed with water.
  - Bases are electrolytes
  - The effect of bases on indicators
  - Neutralization of acids
  - Water solutions of bases taste bitter and feel slippery
  - Have a pH greater than 7
- Describe the properties of salts, including
  - Salts are defined as ionic compounds containing a positive ion other then the hydrogen ion and a negative ion other than the hydroxide ion.
  - High melting points
  - Good conductors of electric current either when molten or when dissolved in water

Assessment

The revised taxonomy verb, summarize means "to abstract a general theme or major point" For this indicator, the major focus of assessment should be to insure that students can differentiate acids, bases and salts in terms of properties and structures. Conceptual knowledge requires that students understand the interrelationships among the basic elements within a larger structure that enable them to function together. In this case, that students understand how the composition of these species affect the way that they react and their physical properties.

C-6.6 Distinguish between strong and weak common acids and bases.

Revised Taxonomy Level 4.1B <u>Distinguish</u> conceptual knowledge

Students did not study this concept in physical science

It is essential for students to

- Understand the difference in the terms strong and concentrated and the difference in the terms weak and dilute
- Recognize and write ionization equations for the following five strong acids
  - HI
  - HBr
  - HCl
  - $HN0_3$
  - H_2SO_4
- Recognize and write ionization equations for the following four strong bases
  - $Ca(OH)_2$
  - $Ba(OH)_2$
  - KOH
  - NaOH
- Differentiate between Arrhenius, Brønsted-Lowry, and Lewis definitions of acids and bases
- Identify conjugate acid/base pairs in ionization reactions and relate the strength of acids and bases to relationship between conjugate acid/base pairs
  - Strong acids produce weak conjugate bases
  - Strong bases produce weak conjugate acids

Assessment

As the verb for this indicator is differentiate (distinguish), the major focus of assessment should be for students to distinguish between the relevant and irrelevant parts of presented materials. Because the verb is differentiate rather than compare, students should be able to not only identify strong and weak acids from a list but also compare the strength of acid/base pairs in ionization reactions.. Because the indicator is written as <u>conceptual knowledge,</u> assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together."

C-6.7 Represent common acids and bases by their names and formulas.

Revised Taxonomy Levels 2.1 B Represent (interpret) conceptual knowledge

Students did not study this concept in physical science

It is essential for students to

- Recognize and differentiate binary acids and oxyacids
- Recognize the names and formulas of common acids including
  - The strong acids listed in C-6.6
  - Acetic acid
  - Carbonic acid
  - Phosphoric acid
- Recognize the names and formulas of common bases including
  - The strong bases listed in C-6.6
  - Ammonia

Assessment

The verb interpret (represent) means that one major focus of assessment will be for students to "change from one form of representation to another", in this case, from the name of the acid or base to the molecular formula of the acid or base, or from the molecular formula to the name.

The following eight indicators (6.8 -6.15) should be selected as appropriate to a particular course for additional content and depth:

C-6.8 Use the hydronium or hydroxide ion concentration to determine the pH and pOH of aqueous solutions.

Revised Taxonomy Level 3.2 C_A Apply (use) procedural knowledge

Students did not study this concept in physical science

It is essential for students to

- Define pH and pOH and relate the definitions to the self-ionization of water
- Use logs and exponents to determine the pH or pOH of a substance from the concentration of the solution.
- Compare pH as determined by pH meters and indicator paper

Assessment

The revised taxonomy verb for this indicator is implement (use). The major focus of assessment will be for students to show that they can "apply a procedure to an unfamiliar task." The knowledge dimension of the indicator, procedural knowledge means "knowledge of subject-specific techniques and methods." In this case the procedure for calculating the pH and the pOH of a solution. A key part of the assessment will be for students to show that they can apply the knowledge to a new situation, not just repeat problems which are familiar. This requires that students have a conceptual understanding of pH and pOH as they apply it to the concentration of hydrogen ions and hydroxide ions in a solution.

C-6.9 Explain how the use of a titration can determine the concentration of acid and base solutions

Revised Taxonomy Levels 2.7 B Explain conceptual knowledge

Students did not study this concept in physical science

It is essential for students to

- Write neutralization equations for the reaction between common selected strong acids and strong bases.
  - (See C-6.14)
- Explain the process of titration.
- Explain how indicators are used in titration
- Use data from the titration of a strong acid by a strong base to identify the equivalence point and the concentration of the acid.
- Analyze the titration curve of a strong acid/strong base reaction and compare the sensitivity of pH change to volume of titrant added

Assessment

The verb, explain means that the major focus of assessment should be for students to "construct a cause and effect model." In this case, assessments will ensure that students can show the effect that increasing quantities of a strong base have on the pH of a strong acid. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments should show that students can construct a cause and effect statement relating how the process of titration can show the equivalence point of the reaction and can therefore be used to determine the concentration of the acid (or the base)

C-6.10 Interpret solubility curves to determine saturation at different temperatures.

Revised Taxonomy Levels 2.1 B Represent (interpret) conceptual knowledge

Students did not study this concept in physical science

It is essential for students to

- Compare the solubility curves of selected solids dissolved in water
  - Understand that the solubility of most solids is directly proportional to temperature, however the degree to which temperature affects the solubility of a solid varies with the structure of the solid
- Compare the solubility curves of gasses in water
  - Understand that the solubility of most gasses is inversely proportional to temperature, however the degree to which temperature affects the solubility of a solid varies with the structure of the solid

Assessment

The verb for this indicator is interpret (represent) the major focus of assessment will be for students to "change from one form of representation to another." In this case, the students should be able to describe the effect that temperature has on the solubility of solids and gasses from a graphical representation. As this indicator is classified as conceptual knowledge, it is vital that students can apply their knowledge of solubility to a solubility graph.

C-6.11 Use a variety of procedures for separating mixtures (including distillation, crystallization filtration, paper chromatography, and centrifuge).

Revised Taxonomy Level 3.2 C_A Apply (use) procedural knowledge

In physical science students

- Classify matter as a pure substance (either an element or a compound) or as a mixture (either homogeneous or heterogeneous) on the basis of its structure and/or composition. (PS-3.4)
  - Students must also understand that when matter is composed of two or more component substances which retain their own identifying properties, the matter is classified as a *mixture*.
    - A mixture can be separated physically because the components of the mixture have different physical properties. Mixtures do not have definite composition; the components of a mixture may be in any ratio.
    - Procedures for separating mixtures include: Dissolving, Filtering, Evaporating, Decanting, Magnetic separation, or Separating by particle size
    - Mixtures can be classified into two groups, heterogeneous and homogeneous.
      - *Heterogeneous mixtures* do not have the components distributed evenly throughout.
      - *Homogeneous mixtures* have components evenly distributed. The components are small that they can not be seen with the naked eye.
  - A *solution* is a homogeneous mixture in which the components are close to the size of individual particles of the substance (atoms, molecules, or ions) and therefore, too tiny to be seen with a microscope.(Ions will be addressed in PS-4.2)
  - Students should know that mixtures can occur among all phases of matter:
    - Gas/gas (air), Gas/liquid (oxygen in water), Liquid/liquid (alcohol in water), Liquid/solid (sugar in water), Solid/solid (alloy such as steel)

It is essential for students to

- Describe what types of mixtures are best suited for each separation process and give examples.
- Apply various process for separating mixtures of various substances
  - Describe the importance of each step in each of the above separation processes to the overall process.
- Understand how differentiation in the properties of the components of the mixture allow for each process

Assessment

The revised taxonomy verb for this indicator is implement (use), the major focus of assessment will be for students to show that they can "apply a procedure to an unfamiliar task". The knowledge dimension of the indicator, procedural knowledge means "knowledge of subject-specific techniques and methods" In this case various procedures for separating a mixture. Assessments should require that students show that they can apply the knowledge to a new situation, not just repeat the exact procedures which they have studied. This requires that students have a conceptual understanding of each process.

C-6.12 Use solubility rules to write net ionic equations for precipitation reactions in aqueous solution.

Revised Taxonomy Level 3.2 C_A Apply (use) procedural knowledge

Students did not study this concept in physical science

It is essential for students to

- Understand and use a hierarchical list of solubility rules to predict whether a compound is soluble or insoluble in aqueous solution.
  - Most sodium, potassium, and ammonium compounds are soluble in water
  - Most nitrates, acetates, and chlorates are soluble.
  - Most chlorides are soluble, except those of silver, mercury (I), and lead. Lead (II) chloride is soluble in hot water.
  - Most sulfates are soluble, except those of barium, strontium, and lead.
  - Most carbonates, phosphates, and silicates are insoluble, except those of sodium, potassium, and ammonium.
  - Most sulfides are insoluble, except those of calcium, strontium, sodium, potassium, and ammonium.
- Predict the formation of a precipitate when aqueous solutions of two soluble ionic compounds are mixed.
  - Write the possible double-replacement reaction
    - $Zn(NO_3)_{2(aq)} + (NH_4)_2S_{(aq)} \longrightarrow ZnS_{(?)} + 2NH_4NO_{3(?)}$
  - Identify the precipitate
    - Zinc sulfide is not a soluble sulfide and is therefore a precipitate
    - Ammonium nitrate is soluble
  - Add the phase symbols to the products in the double replacement reaction
    - $Zn(NO_3)_{2(aq)} + (NH_4)_2S_{(aq)} \longrightarrow ZnS_{(s)} + 2NH_4NO_{3(aq)}$
  - Write the overall ionic equation
    - $Zn^{+2}_{(aq)} + 2(NO_3)^-_{(aq)} + 2(NH_4)^+_{(aq)} + S^{-2}_{(aq)} \longrightarrow ZnS_{(s)} + 2NH_4^+_{(aq)} + 2NO_3^-_{(aq)}$
  - Write the net ionic equation.
    - $Zn^{+2}_{(aq)} + S^{-2}_{(aq)} \longrightarrow ZnS_{(s)}$

Assessment

The revised taxonomy verb for this indicator is implement (use), the major focus of assessment will be for students to show that they can "apply a procedure to an unfamiliar task". The knowledge dimension of the indicator, procedural knowledge means "knowledge of subject-specific techniques and methods" In this case the procedure for using a solubility table and the procedure for writing a net ionic equation. A key part of the assessment will be for students to show that they can apply the knowledge to a new situation, not just repeat problems which are familiar. This requires that students have a conceptual understanding the solubility rules and the process for writing net ionic equations.

C-6.13 Use the calculated molality of a solution to calculate the freezing point depression and the boiling point elevation of a solution.

Revised Taxonomy Level 3.2 C_A Apply (use) procedural knowledge

Students did not study this concept in physical science

It is essential for students to

- Calculate the concentration on a solution in terms of molality (m)
  - moles of solute per mass of solvent
  - moles/kg
- Calculate the freezing point depression of a nonelectrolyte solution using the equation:
  - The change in freezing point (Δt_f) of a solution is equal to the molal freezing point constant (K_f) times the molality of the solution (m).
  - ($\Delta t_f = K_f m$)
- Calculate the boiling point elevation of a nonelectrolyte solution using the equation:
  - The change in boiling point (Δt_b) of a solution is equal to the molal boiling point constant (K_b) times the molality of the solution (m).
  - ($\Delta t_b = K_b m$)
- Understand that the boiling point elevation or melting point depression of an electrolyte is dependent upon the number of moles of particles in the solution.
- Calculate the melting point elevation or boiling point depression of electrolytes
  - Determine the number of moles of particles in solution per moles of solute (molality coversion)
    - $(NH_4)_2S_{(aq)} \rightarrow 2NH_4^+{}_{(aq)} + S^{-2}{}_{(aq)}$
    - 1mole → 3 moles
    - molality conversion is 3moles/1mole
  - ($\Delta t_f = K_f m$ x molality conversion)
  - ($\Delta t_b = K_b m$ x molality conversion)
- Understand that the predicted value for both freezing point depression and boiling point elevation will be greater than the actual values due to deviation of real solution behavior from ideal solution behavior.

Assessment

The revised taxonomy verb for this indicator is implement (use), the major focus of assessment will be for students to show that they can "apply a procedure to an unfamiliar task". The knowledge dimension of the indicator, procedural knowledge means "knowledge of subject-specific techniques and methods" In this case the procedure for determining the freezing point depression or boiling point elevation of both nonelectrolytic and electrolytic solutions. A key part of the assessment will be for students to show that they can apply the knowledge to a new situation, not just repeat problems which are familiar. This requires that students have a conceptual understanding of colligative.

C-6.14 Represent neutralization reactions and reactions between common acids and metals by using chemical equations.

Revised Taxonomy Levels 2.1 B Represent (interpret) conceptual knowledge

In physical science students

- Classify various solutions as acids or bases according to their physical properties, chemical properties (including neutralization and reaction with metals), generalized formulas, and pH (using pH meters, pH paper, and litmus paper). (PS-3.8)

It is essential for students to

- Use an "Activity Series Metals" table to predict whether a metal will replace hydrogen in a given reaction.

More Active

Less Active

Activity Series	
Metals	
Li	React with cold water and acids replacing hydrogen
Rb	
K	
Ba	
Sr	
Ca	
Na	
Mg	React with steam (but do not react with cold water) and acids replacing hydrogen.
Al	
Mn	
Zn	
Cr	
Fe	
Cd	
Co	Do not react with water. React with acids, replacing hydrogen
Ni	
Sn	
Pb	
hydrogen	
Sb	Do not replace hydrogen in water or in acids
Bi	
Cu	
Hg	
Ag	
Pt	
Au	

- Write balanced equations for the reactions between common acids and metals.
- Understand that neutralization of a strong acid and a strong base occurs when the concentration of hydrogen ions [H^+] and hydroxide ions [OH^-] are each at 1 x 10^{-7}M in the solution.
- Use stoichiometry and titration calculations to predict whether various ratios of acid concentration and volume to base concentration and volume will result in a neutral solution.
- Write balanced equations for the neutralization reactions between selected common strong acids and strong bases.

Assessment

The verb interpret (represent) means that one major focus of assessment will be for students to "change from one form of representation to another", in this case, to represent chemical reactions between metals and acids and between strong acids and strong bases with chemical formulas. As this indicator is classified as conceptual knowledge, it is vital that students can apply their knowledge of the chemical reactions of acids and their understanding of chemical equations to represent any given reaction which follows the pattern represented here.